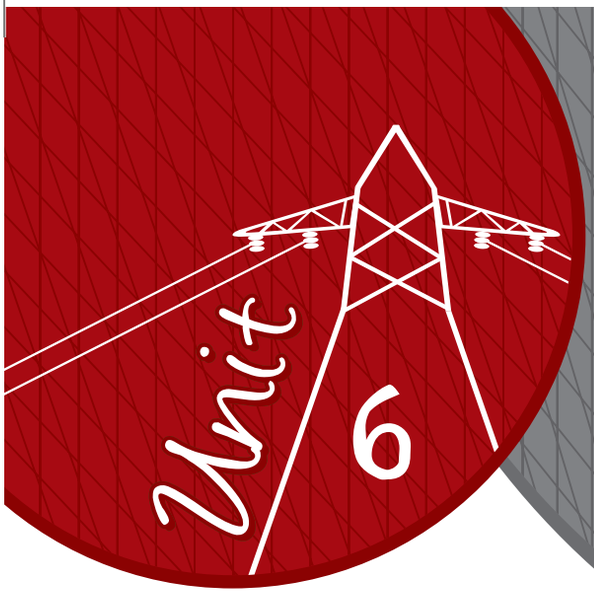


Electrical Safety

Introduction

It is important to follow occupational health and safety standards while dealing with electrical components and appliances. Electric current has enough power that if exposed to, it can be fatal. All electrical systems can cause harm. Electric current may cause the following.

1. Cardiac arrest
2. Muscle, nerve and tissue destruction
3. Thermal burns
4. Falling or injury

Electricity can travel through the body and can interfere with regular electrical signals between the brain and our muscles. This can lead to situations, where the heartbeat, breathing and other body functions may stop. Arc flashes can cause major burns or lead to intense lightning that can cause blindness.

Electrical safety at workplace is regulated by health and safety regulations, which state that every employer is responsible for ensuring that all employees are safe from injuries and other risks at the workplace.

A group, comprising employers and workers, must be formed to identify hazards associated with electrical

Know more...

Electrocution refers to death or severe injury caused by electric shock. When current passes through a human body, it causes electric shock.

equipment. Assessing the risk is imperative to reduce the risk or severity of an injury. Electricity safety training can provide employees with the required knowledge and skill to identify and eliminate risks.

Safety in electrical system

Safety of personnel is important. Therefore, it is necessary to get acquainted with the safety procedures and practices to be followed in all major and minor electrical installations, such as generating stations, transmission and distribution lines, industrial establishment, etc. To get familiar with the safety rules and regulations governing the workplace, it is necessary to know the following rules and regulations.

1. The Electricity Act, 2003
2. The Factories Act, 1948
3. The Workman's Compensations Act, 1923
4. The Payment of Wages Act, 1936

Classes of safety

Following electrical safety measures is the most important thing that must be taken care of while working with an electrical circuit or appliance. Based on some basic factors like earthing, grounding, insulation in the appliance, classes of safety are categorised as follows.

Class 0

- Appliances under this class do not use appropriate earthing connection and have a single level of insulation between live parts and exposed metal work.
- Due to inappropriate earthing, Class 0 safety appliances are used in dry areas only.

Class 1

- In Class 1 safety, the chassis of an appliance must be earthed. If live wires touch the chassis of the appliance, current will flow through the ground or earthed wire.

- A fault in the appliance, which causes a live conductor to contact the casing, will cause the current to flow in the earth conductor.

Class 2

- Class 2 or double insulated electrical appliances are designed in such a way that they do not require a safety connection into the earth (ground).

Class 3

- Class 3 appliances are supplied power from a separate or extra low voltage source.
- Application of safety standards is intended to reduce the risk of injury or damage due to:
  - electric shock,
  - energy related hazards,
  - fire,
  - heat related hazards,
  - mechanical hazards,
  - radiation and
  - chemical hazards.

Work and safety standards

Following the safety standards are important for a company that seeks continuous improvement at the workplace. Standards for operational and safety procedures provide the company with baseline references, which are essential for the business to grow. The standard operating procedures (SOPs) provide a stable platform for performance measurements. A wireman must adhere to the work standards so as to meet the desired targets and achieve sustainability at the workplace. SOPs describe the way of doing a task step-by-step. They document the existing best practices and ensure that they are implemented every time during a task. Every process or machine operation has SOPs and technicians are advised to adhere to the SOPs at all times.

Work standards

In industries, work standards are the thumb rules. Safety standards are designed to ensure the safety of people, products, processes, activities, and so on.

The general guidelines for electrical safety must be followed by the wireman to ensure personal, as well as, co-worker safety. The points given below are some of the general guidelines that must be followed at the workplace.

- Always follow the correct procedures to ensure zero accidents at work.
- Always follow the correct wiring diagram.
- Obey the safety signs, stickers and tags on the control panel.
- Always uses appropriate tools for carrying out a work.
- Never leave a running panel unattended.
- Always read the labels and instructions given on the components.
- Always wear appropriate clothing and remove metal objects before starting a work.
- Use prescribed protective safety equipment only.
- Always follow electrical safety rules when working with electrical machinery or equipment.
- Report all unsafe acts or conditions to the supervisor.

Personal protective equipment

There are some common personal protective equipment (PPE) that must be used at the workplace. Common PPE at the workplace include gloves, helmet, goggles, safety boots, hearing protectors, high-visibility clothing, and so on (Fig. 6.1). Also, there are some special safety equipment available, such as fire extinguishers.

Selection of PPE and other safety equipment must be such that they are suitable for a job and offer the required protection. Items for personal safety are shown in Fig. 6.1. One of the important safety equipment in the electrical and electronic industry is fire extinguisher (fire is a serious hazard in the

industry). If there is a fire in an electrical unit, fire extinguishers are brought into use.

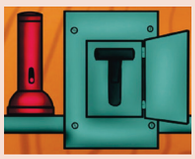
Fig. 6.1 Personal protective equipment

Did You Know?	
Current in milli ampere	**Effect on human body**
0.5–3	Tingling sensation
3–10	Muscle contraction and slight pain
10–40	Let-go threshold
40–75	Respiratory paralysis
100–200	Ventricular fibrillation
200–500	Heart clamp
1500+	Inflammation (burning)

Electricity makes life easier but may also lead to fire. Therefore, all electrical appliances, wires and cables and electric equipment must be handled cautiously. Electrical safety can be achieved by following some basic rules (Table 6.1).

Table 6.1: Electrical safety

Electrical safety is an important aspect that needs to be taken care of while working on an electrical system. Always follow the required safety standards while working with house wiring.	
Electrical house wiring needs undivided attention of people working with the electrical installation system. Do not work in a hurry. Make sure that the work is planned. Make a suitable stopping point. In case of an emergency, one can stop working at that defined stopping point.	
Shut down power to the circuit where work is going on. Use a phase tester and multimeter for testing the circuit in order to make sure that the power is off.	

Always keep a torch or flashlight near the electrical panel, in case of power shutdown.	
Always use wooden or bamboo ladders to carry out an electrical work. Wooden or bamboo ladders are non-conductors. Do not use an aluminium ladder.	
Never work in a wet or damp location. Do not work in rain as it may cause electric shock, and hence, dangerous.	
Always wear shoes having rubber sole, and never work barefoot or with only socks or slippers on. Concrete is conductive, particularly, when damp.	
After shutting off the line to the control panel, always put electrical 'danger' signboard in the panel before starting work. This will be a visual indication for a person approaching towards the panel and the person immediately becomes alert.	
Work with fuse panels instead of breaker panels. When removing a fuse, use only one hand to remove it. Put the other hand either in pocket or behind the back. The reason for doing so is that use of two hands provides a path for electricity to flow through the body.	
Electricity can still flow through one hand and one foot, and pass through the body. But if one follows the precautions as discussed in the Unit, one can minimise exposure to this hazard.	

Protecting oneself

Electricity is a form of energy and this energy cannot be seen with the naked eye. One must be aware of the risks, such as

1. electrocution, which defines electric shocks
2. inflammation, combustion or smoke and gas generation (Fig. 6.2).

Use insulation to prevent electrocution (electric shocks). One must not use spongy material, which can absorb water as water is a good conductor of electricity. The material chosen must be 'plastic', which is nearly waterproof.

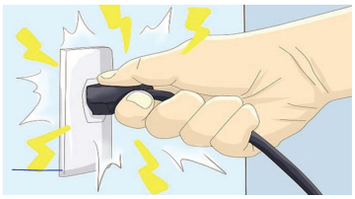


Fig. 6.2 Inflammation while connecting a cord

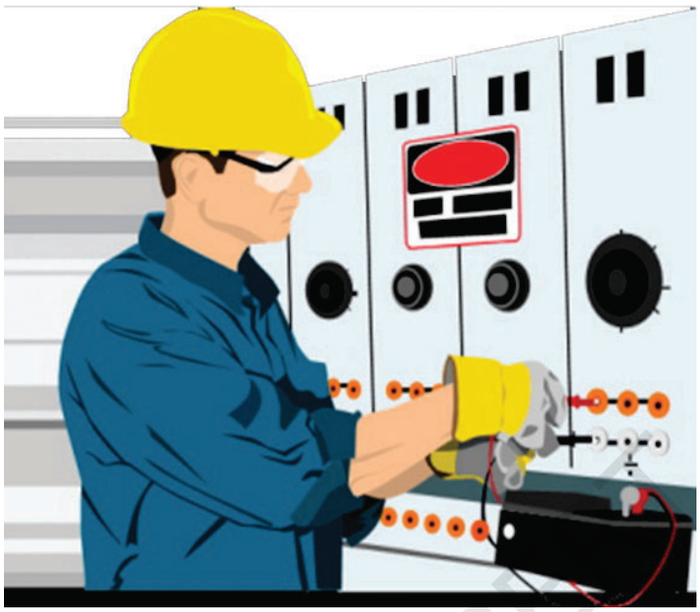


Fig. 6.3 Wireman testing a panel

Use a wire that helps prevent inflammation. Electric energy needs metal wire to transfer from one pole to another. This results in 'current'. This transfer of energy can sometimes heat up the wire, which may cause fire. The heat may cause the wire to become so hot that it

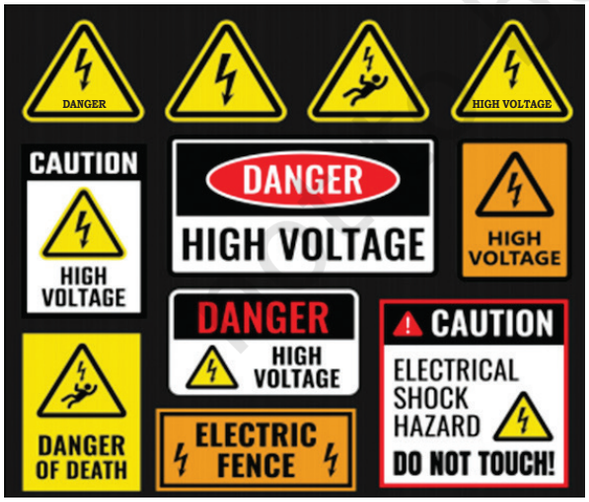


Fig. 6.4 Electrical warning signs

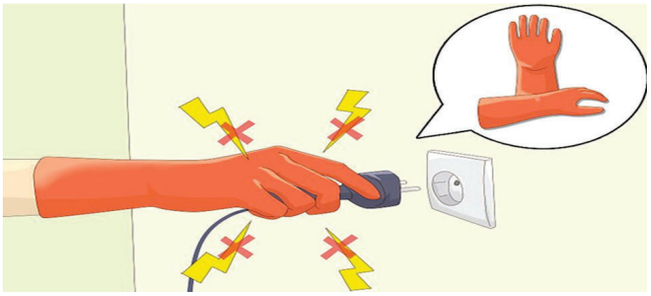


Fig. 6.5 Take precaution while plugging (wear rubber gloves)

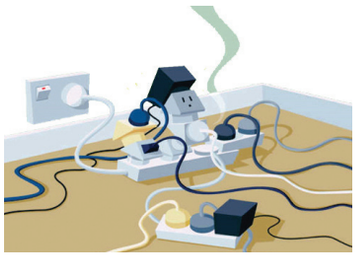


Fig. 6.6 Melted wires produce smoke and poisonous gases

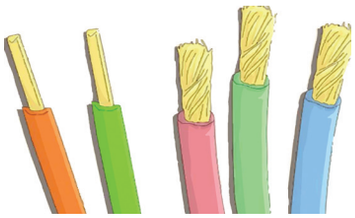


Fig. 6.7 Different size of wires

may melt and burn anything around. Therefore, the insulation also starts melting. Melted insulation will produce smoke and poisonous gas (as shown in Fig. 6.6).

This heating problem can be eliminated by using the appropriate size of wire (Fig. 6.7).

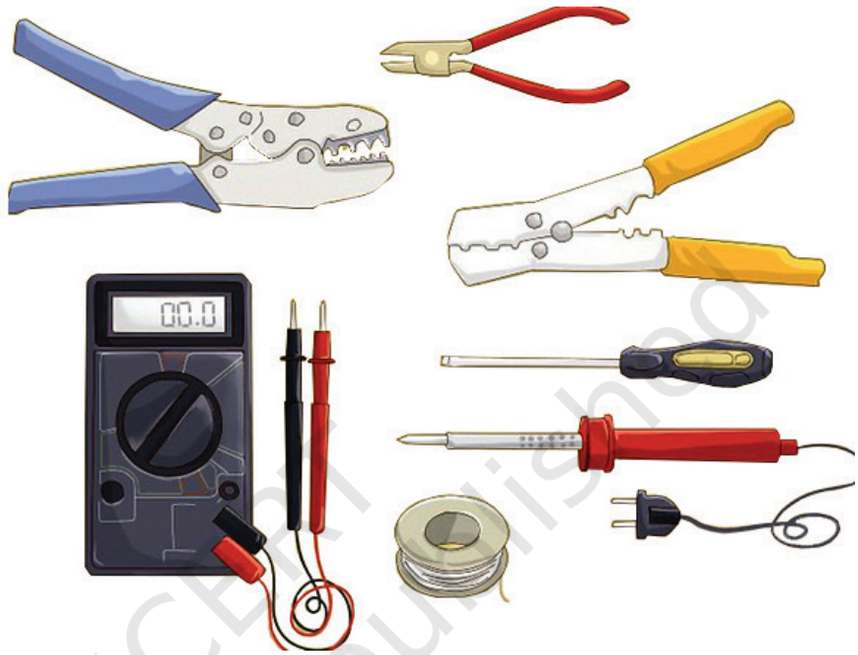


Fig. 6.8 Components in a tool kit

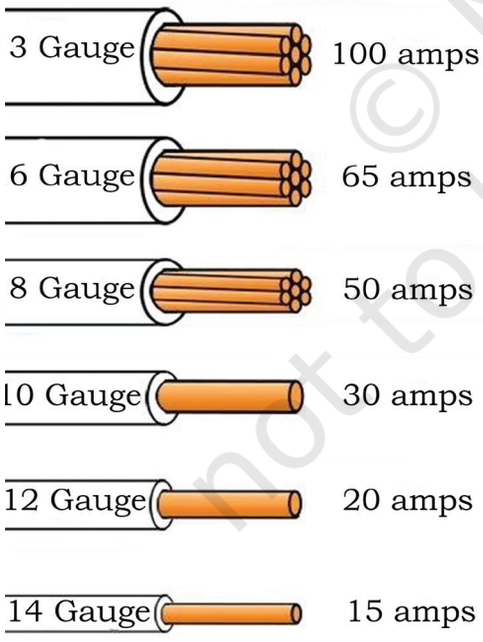


Fig. 6.9 Gauge and amperage of wire

Make sure to use the right tool(s). Always carry necessary tools in the utility box, such as wire cutter, wire stripper, fully insulated screwdrivers, multimeter and soldering station with solder (Fig. 6.8). Add one extra pair of probe wires with 2.5 mm² cross section and one long probe wire of 0.2 mm² cross section with a clamp additional to the multimeter probes, which come with the purchase. This will enable to measure the required value of the probe wires without fire hazard from the electric wires.

For choosing the right dimension of wire, one must consider the gauge and amperage of the wires as shown in Fig. 6.9. Selecting the appropriate dimension of wire is necessary to avoid burning of the insulation, short circuiting, etc.

Electrostatic discharge (ESD)

Electrostatic discharge refers to sudden build-up of static electricity when two differently charged objects are brought together. While manufacturing electronic products, electrostatic discharge is one of the issues that arises as it can cause damage to electronic devices and components. Fig. 6.10(a) represents some causes of ESD.

Fig. 6.10(b) represents some of the ESD prevention guidelines that must be followed to reduce the risk of electrostatic discharge damage to the electric components.

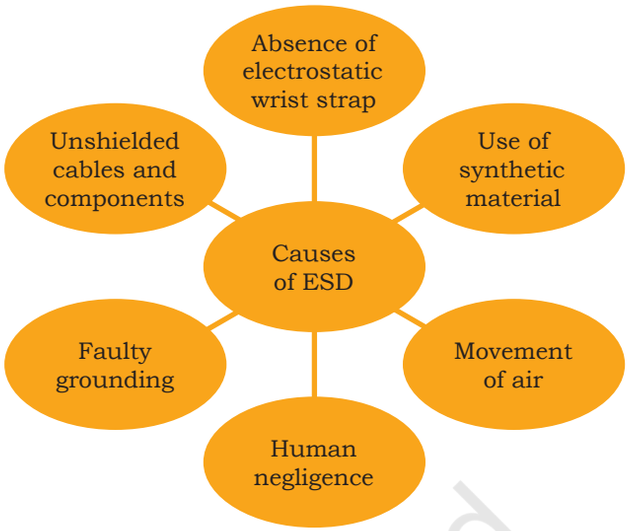


Fig. 6.10(a) Causes of ESD

Causes of ESD

- Faulty grounding
- Movement of charges takes place between the connecting points or printed circuit board
- Human negligence

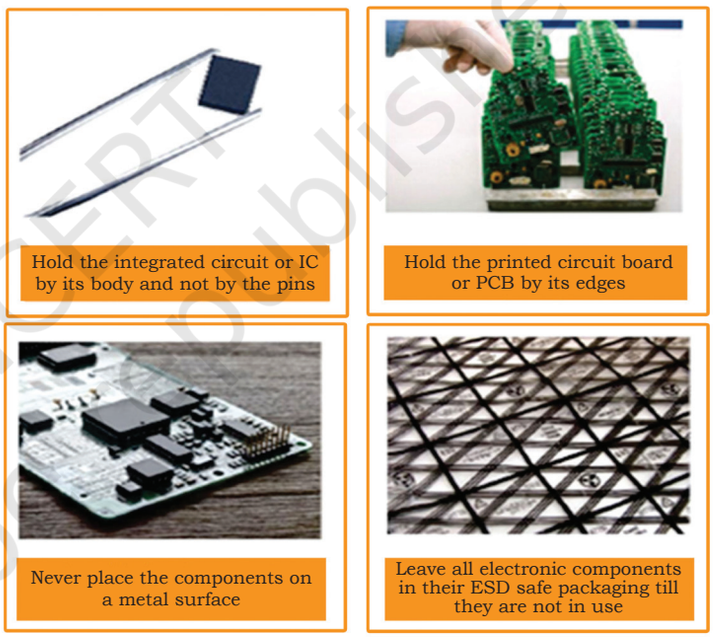


Fig. 6.10(b) ESD prevention guidelines

Electrical conductivity

An electric current results from the motion of electrically charged particles in response to forces that act on them from an applied electric field. In solid material, current arises due to the flow of electrons, which is called 'electronic conduction'. In all conductors, semiconductors and many insulated material, only electronic conduction exists and electrical conductivity is dependent on the number of electrons available to participate in the conduction process. Most metals are good conductors of electricity because of the presence of a large number of free electrons. In water and ionic material like $H_2 SO_4$, Nacl, HCl, etc., a net motion of charged ions can occur. This phenomenon produces electric current and is called 'ionic conduction'.

Know more...

Pure water is distilled water. During distillation, all impurities and ions present in the water are removed. This type of water is not healthy, and hence, unfit for consumption.

Water conductivity

Pure water is not a good conductor of electricity. However, as electric current is transported via ions in the solution, its conductivity increases and the concentration of ions increases.

Electrical conductivity of water is its ability to conduct electric current. Salt or other chemicals like ammonia, hydroflouric acid, etc., that dissolve in water can break down into positively and negatively charged ions. These free ions mixed in water conduct electricity. So, the electrical conductivity of water depends on the concentration of ions. Salinity and total dissolved solids are used to calculate the electrical conductivity of water, which helps to indicate its purity. Higher the purity of water, lower is the conductivity. To give a real-life example, distilled water is almost an insulator, but saltwater is an efficient electrical conductor.

Fuse

A fuse is a short length of wire. It is designed to melt and separate from the circuit in an event of excessive current. Fuses are always connected in series with component(s) to be protected from over current. So, when a fuse blows (opens), it opens the entire circuit and stops the current through the component(s). A fuse connected in one branch of a parallel circuit will not affect current through any of the other branches.

Fig. 6.11 Circuit breaker in the form of fuse

Normally, a thin piece of fuse wire is contained within a safety sheath to minimise hazards in case of an arc blast. The fuse wire opens when electric current flows through it. Sheath is made of a transparent material so that the fusible element can be visually inspected. Residential wiring and glass fuse are commonly used.

Circuit breakers

Circuit breakers are, especially, designed switches. They automatically open to stop the current in case of over current. Small circuit breakers, such as those used in residential, commercial and small industrial areas are thermally operated. They contain a bimetallic strip. A bimetallic strip is a thin strip of two metals bonded back-to-back carrying circuit current, which bends

when heated. When enough force is generated by the bimetallic strip due to over current heating of the strip, the trip mechanism operates and the breaker opens. Larger circuit breakers are automatically operated. They are operated by the strength of the magnetic field. This magnetic field is produced by current carrying conductors within the breaker. Relays can also be used for tripping the circuit breaker. As the circuit breaker is operated automatically by electrical circuit, it does not fail in case of over current. All fuses need to be replaced with miniature circuit breaker (MCB) for safety and control purposes. MCBs are used, primarily, as alternative to fuse in most circuits. A wide variety of MCBs with varied breaking capacity are available in market and used in all areas of domestic, commercial and industrial applications as a reliable means of protection.

Miniature circuit breaker (MCB)

Fig. 6.12 Miniature circuit breakers

It is an electromagnetic device that automatically operates or breaks a circuit, if current in the circuit reaches a predetermined amperage value. It is enclosed in an insulating material. The main function of an MCB is to switch the circuit OFF, i.e., to open the circuit (which has been connected to it) automatically. However, the MCB needs to be switched on manually. When the current passing through it (MCB) exceeds the value for which it is set, then the MCB will get tripped. It can be manually switched 'on' and 'off' similar to a normal switch. MCBs are popularly used for load break, protection and isolation of a sub-circuit, including motor sub-circuits, lighting circuits and control circuits. The main usage area of MCBs is in low-voltage sites, i.e., mainly in domestic, small industrial or commercial applications. These are manufactured in one, two, three and four pole versions of different current and voltage ratings. Similar to fuses, these are used for performing two major functions—over current and short circuit protection. MCBs can replace conventional wire fuse in a distribution board and are designed to operate accurately under both overloading and short circuit conditions. MCBs can be reset quickly by an operator. But in case of a fault, a wire fuse reclosing is

not possible quickly. The tripping of an MCB can easily be identified under overload or short circuit condition as its operating knob moves from 'on' to 'off' position.

MCBs are rated up to 100 amperes. However, the trip current is, normally, not adjustable. It gives a better service for protection because it can operate 5–15 per cent excessive overloads.

Generally, MCBs are used for 230V AC for single phase, 440V AC for three phase or 220V for DC supply. An MCB rated at 10A current, operating on thermal magnetic trip, is the most common type used in modern domestic consumer units and commercial electrical distribution boards.

Construction of MCB

MCB designs are of single pole construction for use in single phase circuits. The complete system is housed within a plastic casing. MCBs are fitted with arc chute stack consisting of various arc chutes (metal plates), which are held in position by an insulating material. It is not necessary that arc chute stack always surrounds the contacts (bimetallic strip). Hence, in some designs, arc runners are provided to move the arc into the arc chutes.

The thermal tripping mechanism consists of a thermal-magnetic arrangement, where thermal action is provided by a bimetallic strip, and in some cases, by a heater. The tripping mechanism is activated by the deflection of the bimetallic strip. A low-resistance bimetal is used for a high current MCB and a higher resistance bimetal for a low current MCB. A heater may be incorporated around the bimetal to generate sufficient heat for low current MCBs. The magnetic tripping mechanism consists of a coil, which is wound around a tube. This tube has a spring-loaded slug and the slug movement operates the tripping mechanism. The magnetic field generated by the coil during high fault current overcomes the spring force holding the slug in position. So, the movement of slug actuates the tripping mechanism. The coil is made of a thin wire with many turns for low rating MCBs and a thicker wire with

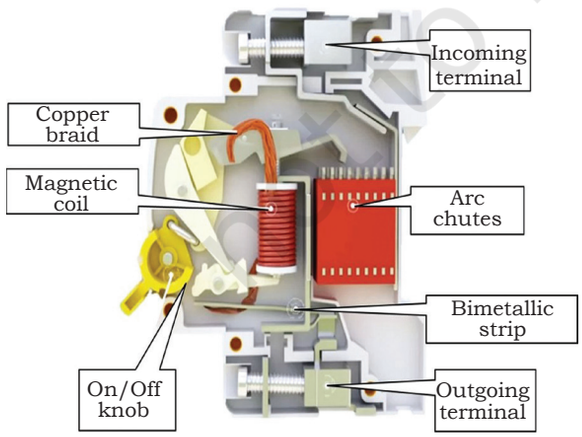


Fig. 6.13 Internal parts of an MCB

fewer turns for higher rating MCBs. Depending on the required characteristics, the magnetic tripping is set by the manufacturer.

Specification of MCB

Company logo

It defines the name of the manufacturing company.

Type number

It defines the type of MCB.

Current rating

It is the current value above which overload protection trips.

Rated voltage AC

It defines the maximum voltage, which can be applied across the terminals of the MCB.

Breaking capacity

It defines the maximum current, which an MCB can withstand without damage.

EN/IEC

It defines the international standard of an MCB.

Energy limiting class

It refers to an energy limiting class number (1, 2 or 3) marked on circuit breakers. It defines the thermal and mechanical stress during operation.

Pin number

It defines the number of MCB terminals.

Poles

It defines the numbers of poles of the MCB.

Pole interlock

It defines the interlocking of poles.

Thermal protection

It defines the thermal protection in the MCB. This protects the MCB or circuit from high thermal energy produced by current.

Magnetic protection

It defines magnetic protection in the MCB. This will protect the MCB or circuit from magnetic effects of current.

Knob

It is used for turning the MCB 'on' or 'off'.

Label

It can be inserted in the holder fitted with a transparent cover. It helps to name multiple circuits on the distribution board.

True contact indication flag

It defines the MCB's indication of whether it is open or close. Red or green colour flag provides a clear visual indication of the contact status inside.

Earthing pit

Nowadays, earth pits are the preferred method for earthing, especially, for electrical works. Electricity always follows the path of least resistance. To divert maximum current away from a circuit, earthing pits are designed. The size of the pit plays a vital role in earthing. Earthing or grounding an electrical network is an essential safety measure, which can protect equipment from electrical faults and save human beings and animals from electric shocks.

Need for earthing electrical networks

Electrical networks are earthed for three main purposes, which are as follows.

1. An earthed circuit reduces the risk of death or injury by providing an alternative path for current to discharge into the ground. Equipment, appliances and property are protected against faults, leaks and fires resulting from short circuits and sparking.
2. Earthing also provides protection against power surges, accidental connection with high-voltage lines and even lightning strikes, allowing the energy to flow into the ground, with minimal effect.
3. Ground offers a common point of reference for calculating the relationship between different voltage sources. It has been used as a universal standard since the introduction of distribution system.

Practical Exercise

Practical Exercise 1

Demonstration of earthing

Material required

Tools for excavation, charcoal and salt, GI pipe, copper, GI wire

Procedure

1. An area of 1.5 × 1.5m is excavated to a depth of 3m.

Fig.1 Making a pit for earthing

2. The pit is half filled with a mixture of charcoal and salt.
3. A 500 × 500 × 10mm plate (earth plate) is placed in the centre of the pit.

Fig. 2 Copper plate set in the pit

4. Connections between the earth plate and surface are installed for system earthing. The rest of the pit is filled with charcoal, sand and salt mixture.

Fig. 3 Copper plate and surface are connected with a pipe

5. To connect the earth plate to the surface, two GI strips with a cross section of 30 × 10mm can be used. Additionally, the top of the pipe can be covered with a T-section to prevent mud, sand and stones from clogging it. In summers, the pit must be watered to prevent it from drying out.

Fig. 4 Pit filled with mud, sand and stones

Check Your Progress

A. Multiple choice questions

1. Appliances of which class have no protective earth connection and feature only a single level of insulation between live parts and exposed metal work.
   (a) Class 0
   (b) Class 1
   (c) Class 2
   (d) Class 3
2. Sudden build-up of static electricity when two differently charged objects are brought together is called _____.
   (a) electrostatic energy
   (b) electron motion
   (c) electrostatic discharge
   (d) electrostatic potential
3. Which tool is used for removing insulation from the wire?
   (a) Screwdriver
   (b) Pliers
   (c) Nose pliers
   (d) Stripper
4. ESD stands for _____.
   (a) Electrostate display
   (b) Electrostatic display
   (c) Electrostatic discharge
   (d) Electrostate discharge

5. Double insulated or _____ electrical appliance is one, which is designed in a way that does not require a safety connection into the earth (ground).
   (a) Class 0
   (b) Class 1
   (c) Class 2
   (d) Class 3
6. _____ appliance is designed to be supplied from a separated or safety extra-low voltage power source.
   (a) Class 0
   (b) Class 1
   (c) Class 2
   (d) Class 3
7. Which of the following dimensions is used for copper plate in plate earthing?
   (a) 600 × 600 × 12mm
   (b) 600 × 600 × 6mm
   (c) 600 × 600 × 3.5mm
   (d) 600 × 600 × 15mm
8. Which of the following dimensions is used for galvanised iron plate in plate earthing?
   (a) 600 × 600 × 12mm
   (b) 600 × 600 × 6mm
   (c) 600 × 600 × 3.5mm
   (d) 600 × 600 × 15mm
9. Which of the following dimensions is used for cast iron plate in plate earthing?
   (a) 600 × 600 × 6mm
   (b) 600 × 600 × 12mm
   (c) 600 × 600 × 3.5mm
   (d) 600 × 600 × 15mm
10. What will be the impact on the conductivity of water if it gets purified?
    (a) Conductivity of water will increase
    (b) Conductivity of water will decrease
    (c) Conductivity of water will remain the same
    (d) Conductivity of water does not depend on purity

B. Fill in the blanks

1. Electricity always follows the least _____ path.
2. Bimetallic strip is a part of _____.
3. A miniature circuit breaker has two states, i.e., open and _____.
4. Pure water is bad _____ of electricity.
5. ESD stands for _____.
6. Electrical safety at workplace reduces _____.
7. Class 0 safety is used only in _____ area.
8. One must follow the safety _____ and tags on the control panel.

NOTES

9. Current of 40–75 mA will cause _____.
10. Heating problem can be eliminated by using the _____ of wire.

C. State whether the following statements are True or False

1. A wireman should always follow the correct wiring diagram.
2. A wireman must follow the safety signs, stickers and tags on the control panel.
3. It is not necessary to read labels and instructions given on the components.
4. A wireman wears appropriate clothing and removes all metal objects before working.
5. One must use only the prescribed protective safety equipment.
6. Always follow the safety rules when working with electrical machinery or equipment.
7. Electrostatic discharge can cause damage to the electronic devices and components.
8. When removing a fuse, use only one hand.
9. After shutting off a line, always put danger signboards in panels before starting a work.
10. Distilled water is a good conductor of electricity.

D. Short answer questions

1. What can be the causes of electrostatic discharge?
2. What is electrocution?
3. List the tools required for carrying out electrical work.
4. What will be the hand position of a wireman while working with a fuse panel?
5. What testing can be performed for confirming that power of a device is off?
6. Which ladders are used at workplace?
7. What are the general guidelines that a wireman needs to follow at the workplace?